SYNOPSIS OF RESEARCH PROJECT

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8.	**Title of Research Project**	**:**	**DEVELOPMENT AND PERFORMANCE EVALUATION OF A PEANUT STACK FORMATION ATTACHMENT TO THE EXISTING GROUNDNUT DIGGER SHAKER**

9. Introduction

9.1 General

Groundnut (*Arachis hypogaea* L.) commonly known as peanut, belongs to the legume family. The scientific name is derived from Greek words: *Arachis* meaning legume and *hypogaea* meaning “below ground,” which refers to its unique characteristic of pod development beneath the soil surface. The crop is believed to have originated in the valleys of Paraguay in South America. It is an annual herbaceous plant that typically grows to a height of 30–50 cm. Groundnut is also known by several common names such as earthnut, monkey nut, goober pea and pig nut. In the global oilseed market, India maintains a pivotal role, consistently securing its status as the second-highest producer of groundnuts. The crop is predominantly cultivated by small and marginal farmers, especially in semi-arid regions, where it plays a crucial role in livelihood and agricultural sustainability (Govindaraj and Mishra, 2011).

9.2 Origin of Groundnut

Groundnut is considered to have originated in South America, particularly in regions around Paraguay and Brazil. Historical records indicate that the crop was discovered in the early 16th century and later introduced to other parts of the world, including India, during the same period through trade and missionary activities. The varieties cultivated in India today are largely believed to have Brazilian lineage, although they have undergone significant adaptation over time.

9.3 Composition in groundnut

Groundnut kernels are highly nutritious and rich in essential components. They contain approximately 43-49% oil, 28-30% protein and 16-24% carbohydrates. The protein content is significantly higher compared to many common food sources. Groundnuts are also a valuable source of vitamins such as A, B-complex (B1 and B2) and E. In addition to their nutritional value, groundnut by-products are also economically important. The oil extracted is widely used for cooking as well as in industries such as soap and hydrogenated oil production. Groundnut cake, a by-product of oil extraction, is rich in protein and serves as an excellent organic manure and livestock feed. The plant residues are used as fodder, while shells are commonly utilized as fuel. Due to its multiple uses, groundnut contributes significantly to the agricultural economy.

9.4 World groundnut scenario

Groundnut is a major oilseed crop in India, occupying the largest area among oilseeds and ranking second in production after soybean. Globally, China is the leading producer, followed by India, with other significant producers including Nigeria, Sudan and the United States. In India, groundnut cultivation is mainly concentrated during the kharif season. Recent estimates indicate that production levels have remained relatively stable, although there has been a slight decline in the area under cultivation in recent years. Gujarat accounts for the largest share of groundnut area, followed by states such as Rajasthan andhra Pradesh, Madhya Pradesh, Karnataka and Telangana. (Anon., 2023). The Saurashtra region of Gujarat is particularly known for extensive groundnut cultivation and is often referred to as the “groundnut bowl” of the state. Groundnut is cultivated in more than 100 countries worldwide and is recognized as one of the major sources of edible oil and plant-based protein. In India, it contributes significantly to meeting the country’s edible oil demand. Several improved varieties of groundnut have been recommended for cultivation in different seasons in Gujarat. These varieties are

broadly classified based on their growth habit into spreading, semi-spreading and Spanish bunch types (Anon., 2023).

Table 1. State wise are under groundnut in India (Anon., 2023)

State	2021-22		2022-23	
	Area (lakh ha)	% to Tota Area	Area (lakh ha)	% to Tota Area
Gujarat	19.10	38.63	17.09	37.49
Rajasthan	7.77	15.72	7.90	17.33
Andhra Pradesh	6.42	12.99	5.47	12.00
Karnataka	4.90	9.91	3.73	8.18
Madhya Pradesh	3.88	7.85	5.50	9.87
Telangana	0.12	0.24	0.08	0.18
Others	7.25	14.66	6.82	14.96
All India	49.44	100.00	45.59	100.00

Groundnut has been a dominant crop in the Saurashtra region of Gujarat for more than a century, playing a vital role in the agricultural economy of the area. It is widely cultivated across the globe, being grown in over 100 countries under diverse agro-climatic conditions. Globally, groundnut ranks among the major oilseed crops, serving as the fourth largest source of edible oil and the third most significant contributor of plant-based protein.

In India, groundnut is one of the most important oilseed legumes and contributes nearly 30 percent of the nation’s edible oil requirement. The major groundnut-producing states include Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu and Maharashtra, which together account for more than 85 percent of the total cultivated area and production in the country. Optimizing oilseed yields within the Indian agricultural landscape is fundamentally linked to the integration of precision mechanization. Specifically, the development and implementation of site-specific technological interventions tailored for groundnut farming are critical for overcoming current productivity bottlenecks.

The Saurashtra region serves as the primary hub for groundnut production in Gujarat, earning its reputation as the state’s "groundnut bowl" (Hadiya *et al*., 2014). To support this intensive cultivation, several high-yielding cultivars have been developed and endorsed for specific agro-climatic windows, including the kharif and rabi seasons,

as well as versatile varieties capable of thriving in both (Anon., 2015a). Based on growth habit and plant structure, these varieties are generally classified into spreading, semi-spreading and Spanish bunch types, as detailed in Table 1 and Table 2.

Table 2. Different groundnut varieties of Gujarat (Season wise)

***Kharif* (rainy) season**	***Rabi* (summer) season**	***Kharif* (rainy) and *Rabi* (summer) season**
GG - 20, GG - 7, GG - 5, JL - 501, GJG - 31, LGN - 2, GJG - HPS - 1, GJG 17, GJG – 22	TPG - 41, GG - 6, GJG – 9 (J - 69), TG -26	TG - 37A, GG - 2, Dh - 86

Table 3. Groundnut varieties as per their habitat group

Spreading type	**Semi-spreading type**	**Spanish bunch type**
GJG - HPS - 1, GJG – 17 and GJG - HPS - 2	GG - 20 and GG - 22	GG - 5, GG - 7, GJG - 9, GJG - 32, GG - 6, TPG - 41, GJG - 31, GG - 2 and TG – 37 A

9.5 Mechanization in groundnut harvesting

Farm mechanization plays a crucial role in enhancing both the economic viability and social well-being of farmers. One of the major economic advantages of mechanization is the increase in crop yield due to timely and efficient field operations. In recent years, the adoption of agricultural machinery in India has expanded significantly, contributing to higher productivity and profitability. Mechanization enables precise application of inputs, reduces dependence on manual labour and ensures better utilization of resources. Continuous advancements in machinery design, improved materials and modern manufacturing techniques have further strengthened the scope of farm mechanization to meet the evolving needs of agriculture (Manian *et al*., 2002).

In groundnut cultivation, labour scarcity and the need for timely operations make mechanization particularly important. Mechanized approaches help reduce the physical strain associated with traditional practices and improve overall operational efficiency. By ensuring timely completion of farm activities, mechanization enhances cropping intensity and minimizes input losses. It also increases precision in operations,

leading to better utilization of seeds, fertilizers and water, ultimately improving crop performance (Ranjan *et al*., 2014).

Groundnut harvesting involves uprooting the entire plant along with the pods from the soil. It is generally recommended to carry out harvesting during clear and sunny weather to allow proper drying of plants and pods in the field. Harvest timing is critical, as both premature and delayed harvesting can lead to significant yield losses. Early harvesting results in immature kernels with poor quality and reduced weight, while delayed harvesting can cause pod detachment due to weakening of pegs, leading to higher field losses (Singh and Oswalt, 1995).

Various methods are currently used for groundnut harvesting, including manual uprooting, hand tools, animal-drawn diggers and tractor-operated implements. Manual methods are labor-intensive, time-consuming and often uneconomical, especially when pods are located deeper in the soil (6.5 to 10 cm). Although animal-drawn diggers offer some improvement over traditional practices, they still involve considerable labour and operational costs. For small and medium-scale farmers, tractor-powered implements serve as an effective intermediate solution, providing better efficiency and timeliness.

In regions like Saurashtra, farmers commonly use bullock-drawn and tractor-drawn blade harrows for harvesting spreading varieties of groundnut. However, these implements often face operational challenges such as clogging due to vines and inadequate soil penetration under hard soil conditions. These limitations result in a higher percentage of pods remaining in the field, reducing overall efficiency. Consequently, there is a growing demand for improved tractor-operated harvesting equipment that can overcome these issues (Vagadia *et al*., 2015).

In large-scale agricultural frameworks, the transition to automated harvesting and threshing systems is a critical strategy for mitigating labor shortages and optimizing operational timelines. Mechanized harvesting facilitates the simultaneous extraction of plants and pods, while subsequent threshing isolates the pods from the root structures. Integrating these processes significantly enhances groundnut productivity by reducing post-harvest losses and minimizing the time-intensive nature of manual labor.

10. Practical Utility of the Research Project

In the present agricultural scenario, a significant shortage of farm labour has emerged due to factors such as urbanization, changing lifestyles and increasing reliance on mechanization. This labour scarcity creates difficulties for farmers in performing

timely field operations, often leading to higher operational costs. As a result, many farmers are gradually moving away from cultivating labor-intensive crops.

Existing groundnut digger shaker machine primarily focus on uprooting and soil separation, but they lack an efficient mechanism for uniform stack formation. Therefore, there is a strong need to develop an attachment that can automatically form uniform stacks behind the digger shaker. This attachment reduce dependency on manual labour and improve operational efficiency. By integrating stack formation with the existing digger shaker done multiple operations are combined into a single pass, field capacity is increased, fuel and operational costs are reduced. At the time of groundnut harvesting key challenges like labor shortage, in-efficiency in stacking, crop losses due to not stack at proper time and method. So, enhances the overall efficiency of harvesting operations.

Properly formed stack ensure better aeration, uniform exposure to sunlight, reduced moisture content. So, mechanized stacking system contributes directly to post-harvest quality improvement. Manual stacking of the groundnut plant is labor-intensive, time consuming, costly due to increasing labor wages. So, developing a stack formation attachment will significantly reduce dependency on manual labor and improve operational efficiency.

Consequently, additional labour and time are required to gather the uprooted groundnut plants after harvesting. Delays in collection can lead to leaf shedding due to prolonged exposure to sunlight, resulting in the loss of valuable fodder. Moreover, incomplete collection often leaves behind pods and plant residues in the field, reducing overall harvesting efficiency.

To enhance the efficiency of current mechanized harvesting, it is essential to engineer an auxiliary component for existing groundnut digger-shakers that enables real-time plant collection or windrowing during the digging process. Integrating such a mechanism is expected to significantly decrease manual labor dependency, mitigate post-harvest losses, and optimize operational expenditures. Consequently, this study focuses on the design and structural development of a specialized peanut stacking attachment tailored for compatibility with conventional digging and shaking machinery.

11. Objectives

1. To study the existing methods of groundnut harvesting.

2. To develop a peanut stack formation attachment to the existing groundnut digger shaker.
3. To evaluate the performance of modified groundnut digger shaker.
4. To study the economics of modified groundnut digger shaker.

12. Review of Literature

The present section provides a comprehensive overview of previous research carried out by various investigators relevant to the selected study. It summarizes the findings from published literature on diggers used for harvesting different crops, with particular emphasis on their design features and operational aspects. The collected information has been systematically reviewed and organized under the following headings to facilitate a clear understanding of the subject.

12.1. Crop parameter

Vennela *et al*. (2018) investigated key physiological characteristics of groundnut plants to support the design of a combine suitable for handling pre-threshed crops. For efficient operation of such a machine, parameters such as plant height and plant weight are essential, as they influence crop conveying and feeding into the threshing unit. The study was therefore conducted to obtain relevant design data. Observations were recorded at 30, 60 and 90 days after sowing, as well as at harvest. The measured parameters included plant height, canopy spread, root length, number of pods per plant, number of unfilled pods and plant population, all of which are important for developing an efficient harvesting system.

Damor *et al*. (2019) evaluated the influence of planting geometry and integrated weed management practices on kharif groundnut production. Experimental trials were carried out at the Agronomy Instructional Farm of the Chimanbhai Patel College of Agriculture in Sardarkrushinagar. Results indicated that mechanical interculturing followed by manual weeding at 25 and 40 days after sowing effectively minimized weed infestation and enhanced crop yield. The highest productivity and economic returns were achieved with a paired row spacing of 30-60-30 cm combined with interculturing and hand weeding at the specified intervals. In situations where labour availability is limited, effective weed control can be achieved through pre-emergence application of pendimethalin at 1.0 kg/ha, supplemented with interculturing and a single hand weeding at 30 days after sowing.

Nageswar *et al*. (2022) conducted a study to determine soil and crop parameters required for the design and development of a groundnut digger-cum-stripper. Both soil

characteristics and plant attributes play a significant role in designing harvesting and processing equipment, influencing factors such as digging depth, blade inclination, operating speed, crop pickup height, conveyor velocity and stripping mechanism parameters. The study focused on groundnut varieties Kadiri-6 and Dharani. The average soil penetration resistance, bulk density and moisture content were found to be 1531 kPa, 1.54 g/cm³ and 11.26%, respectively. For Kadiri-6, the mean plant height, canopy width, root length, number of branches and pod distribution depth were recorded as 37.2 cm, 27.8 cm, 15.5 cm, 5.2 and 4.6 cm, respectively. Similarly, for the Dharani variety, the corresponding values were 42 cm, 24.8 cm, 15.4 cm, 7.2 and 4.2 cm.

12.2. Harvesting losses

Singh and Memon (1983) conducted an investigation on harvesting and post-harvesting losses in groundnut under Gujarat conditions. Research suggests that the moisture levels present during both harvest and storage are critical determinants of total crop loss. Specifically, data indicates that the harvesting phase is the most vulnerable period for pod loss, outperforming subsequent processing stages in terms of damage magnitude Table 4.

Table 4: Post harvest losses in groundnut

Sr. No.	Operation	Pod loss (%)
1.	Harvesting	16-47
2.	Curing/Drying	5-50
3.	Threshing	10-20
4.	Storage	1-2

Nautiyal *et al*. (2001) reported that pod losses during harvesting can be significant, ranging from 20 to 30 percent. These losses were observed to be higher in Virginia-type groundnut varieties compared to Spanish types. The extent of losses largely depends on the harvesting method and the soil moisture level at the time of digging. Inappropriate soil moisture conditions can weaken peg strength, particularly in Virginia varieties, leading to higher pod detachment and deterioration in crop quality. Therefore, maintaining optimal soil moisture during harvesting is crucial for minimizing losses.

Mishamandani *et al*. (2014) carried out a comparative evaluation of harvesting losses in peanut crops under mechanical and manual methods. The experiment was

conducted in a field located in Astaneh-Ashrafiyeh, which was divided into three plots two designated for mechanical harvesting and one for manual harvesting. Research indicates a clear trade-off between efficiency and precision in harvesting methods. For instance, peak performance in mechanical harvesting was observed at a forward speed of 1.8 km/h and a soil moisture level of 19.9%. While manual harvesting yielded a significantly lower total pod loss (3.487%) compared to mechanical methods (20.23%), the latter remains advantageous due to its superior operational speed and reduced labor expenditures.

12.3. Factors affecting harvesting losses

Ahmad *et al*. (1987) introduced a tractor-mounted prototype for digging and lifting groundnuts, specifically engineered to optimize field efficiency and recovery rates. The machine incorporated dual digging blades that penetrate beneath the crop row to loosen soil and sever the taproot. Lifting rods attached to the blades elevate the uprooted plants onto a conveyor system. The mechanical conveyor system serves a dual purpose: facilitating soil separation through agitation while simultaneously transporting crops to the discharge point. Initial performance metrics recorded at an operating velocity of 0.9 km/h demonstrated a field capacity of 0.5 ha/h. Despite an observed operational efficiency of 63%, the system successfully processed an average yield of 126 kg/ha.

Ademiluyi *et al*. (2011) evaluated a tractor-powered digger-shaker, noting that its operational success is highly dependent on the moisture conditions of the field at the time of use. Their findings emphasized that soil moisture plays a critical role in determining digging efficiency, with an optimal range identified between 12% and 15%. The study also highlighted the importance of timely harvesting, as delays significantly reduce machine efficiency. Additionally, operational parameters such as forward speed and conveyor inclination angle were found to have considerable influence on overall machine performance.

Afshin *et al*. (2014) assessed the performance evaluation of a walking-type tractor-operated peanut harvester under different soil moisture levels (24.79%, 21.06% and 20.55%) and forward speeds (1.7, 2.5 and 3.3 km/h) in Iran. The results indicated that soil moisture significantly affected the percentage of unexposed pod losses, whereas forward speed did not show a significant impact on various loss parameters, including damaged, exposed, unexposed and undug pods. The study concluded that

mechanical harvesting reduces both harvesting losses and operational costs compared to manual methods.

Afshin *et al*. (2014) examined the differences in harvesting losses between mechanical and manual techniques. At a forward speed of 1.8 km/h and a soil moisture level of 19.9%, the lowest losses were noted. Statistical analysis revealed significant differences between the two methods for most parameters, except undug pods at the 1% significance level. Total pod loss was observed to be 3.487% in manual harvesting and 20.23% in mechanical harvesting. Although mechanical harvesting reduced labor costs, the increased losses led to higher overall economic losses, suggesting limited suitability under certain conditions.

Bako *et al*. (2015) assessed a tractor-mounted groundnut harvester at various forward speeds (2, 3, 4, and 5 km/h) while keeping the digging depth constant at 10 cm. According to the study, pod damage rose as speed increased but harvesting efficiency declined. At 2 km/h, the highest efficiency of 75.3% was attained, and at 5 km/h, the lowest efficiency of 63.7% was noted. In a similar vein, pod damage peaked at 5 km/h (34.2%) and decreased to 17.1% at 2 km/h. Forward speed has a substantial impact on damage and efficiency, according to statistical study.

Nagendra *et al*. (2023) examined the influence of design and operational parameters on the mechanical harvesting of ginger. Different blade geometries (straight, inverted V and crescent) were tested at rake angles of 15°, 20° and 25°, along with forward speeds of 2.0, 2.5 and 3.0 km/h. At a rake angle of 20° and a speed of 2.5 km/h, the inverted V blade worked well. Conveyor performance was also evaluated using elevator angles (15°, 20° and 25°) and speed ratios (1.0, 1.25 and 1.5), with optimal results obtained at a 20° angle and 1.25 speed ratio. Under these combined conditions, the system achieved superior performance, including minimum draft requirement (2431.57 N), high digging efficiency (99.20%), minimal crop damage (1.0%) and reduced fuel consumption (4.72 L/h).

12.4. Existing groundnut diggers

Mohanty *et al*. (2005) designed and evaluated a sweep-type groundnut digger to assess its field suitability. The machine was tested on the bunch variety AK-1224, considering parameters such as power requirement, field capacity, field efficiency, pod loss and digging efficiency. Its performance was compared with the CIAE Bhopal model and showed superior results. Compared to the CIAE model (0.94 hp), the developed digger used less power (0.61 hp). At an operating speed of 1.59 km/h, it

attained a field capacity of 0.132 ha/h with 70% field efficiency. Digging efficiency was 86.73%, but the overall pod loss was 13.27%. The operational cost was estimated at ₹203.80 per hectare.

Ibrahim *et al*. (2008) introduced a multi-crop digging implement capable of harvesting both peanuts and potatoes, highlighting a move toward adaptable machinery in root crop production. The machine incorporated a vibrating separation mechanism to reduce losses and mechanical damage. Performance evaluation was conducted at forward speeds of 1.4, 1.8 and 2.3 km/h and tilt angles of 120°, 180° and 240°. Results indicated that the inclusion of vibration significantly reduced losses from 13.7% to 3.1% and mechanical damage from 2.75% to 0.6% in peanuts. Harvesting efficiency improved from 93% to 95.12% with vibration. The optimal operating conditions were identified as 15 cm digging depth, 2.3 km/h forward speed and 120° tilt angle.

Bhutada *et al*. (2010) introduced tractor-operated attachments for shaking and pod exposure in groundnut harvesting. In terms of mechanical performance, the digger-shaker unit exhibited an average draft requirement of 782 kg at a velocity of 3.79 km/h. In contrast, the pod exposure unit required a lower draft of 691 kg, despite operating at a higher speed of 4.28 km/h. The performance evaluation of the harvesting machinery revealed that the digger-shaker achieved an effective field capacity of 0.35 ha/h with an efficiency of 80.10%. In comparison, the pod exposure unit demonstrated superior performance, recording a capacity of 0.41 ha/h and a field efficiency of 81.33%. Digging efficiency reached 90%, while pod exposure efficiency was 93.28%. Fuel consumption ranged between 3.7 and 4.14 L/h.

Alexandru *et al*. (2011) investigated mechanized peanut harvesting under Romanian conditions. To assess the impact of water availability, experimental trials utilized 20 m plots featuring inter-row spacing ranging from 0.5 to 0.7 m. Performance indicators included plant extraction rate, pod detachment, material purity and total losses. The results confirmed satisfactory machine performance within operating speeds of 0.61-0.92 m/s and pulling device speeds of 1.56-2.00 m/s.

Yulan *et al*. (2012) developed a cassava harvesting prototype comprising a digging shovel, clamping conveyor and power transmission system. Key design parameters included a shovel angle exceeding 20°, a shovel length of 550 mm and width of 1000 mm. The transmission system had a total ratio of 2.29, with gearbox output speed of 500 rpm and final output speed of 435 rpm. Field tests demonstrated stable operation and effective integration of digging and pulling functions.

Mareppa *et al*. (2014) focused on optimizing operational parameters of a self-propelled groundnut digger. The study reported a maximum digging efficiency of 96.95% with a draft requirement of 1558 N. The effective field capacity and field efficiency were observed as 0.08 ha/h and 80%, respectively.

Vagadia *et al*. (2015) evaluated a tractor-operated groundnut digger-shaker at the instructional farm of Junagadh Agricultural University. The machine consisted of a digging blade, frame, PTO-driven transmission and shaking mechanism. The average draft was 782 kgf at 3.8 km/h speed with a digging depth of 12 cm. Power requirement ranged from 11 to 12 hp. The effective field capacity was 0.35 ha/h with 80% field efficiency and fuel consumption was 3.7 L/h. The machine significantly reduced labor and operational costs.

Oda *et al*. (2018) investigated the performance of a prototype carrot harvester by examining the interaction between mechanical settings and harvesting efficiency. The study established that optimal results were achieved using a forward speed of 2 km/h and a lifting belt speed of 2 m/s, which resulted in a kinematic factor of 3.57. These operational parameters, combined with a 30° belt inclination and a 15° share rake angle, yielded a lifting efficiency of 98.54% and a field efficiency of 92.50%. Crucially, the mechanized system proved to be highly cost-effective, reducing total harvesting expenses by 80.74% relative to traditional manual methods, while maintaining minimal crop loss at 0.18 Mg/fad. This research highlights the potential for precision-tuned machinery to maximize field capacity while significantly lowering the economic burden of carrot production.

Vennela *et al*. (2018) designed and evaluated a tractor-operated groundnut digger-shaker along with a fresh pod thresher. The maximum effective field capacity achieved by the digger-shaker was 0.35 ha/h. Research by the authors indicated that field efficiency peaked at 80.10% when soil moisture was maintained at 12%. Evaluations of haulm collection over a 10 m span showed proportional increases in yield as the number of rows increased, specifically measuring 1.011 kg, 2.128 kg, and 3.518 kg for one, two, and three rows, respectively. Furthermore, testing of the wet pod thresher at a feeding rate of 870 kg/h yielded an output of 227.25 kg/h, requiring a labor force of six individuals to sustain operations.

Kavad *et al*. (2020) developed a groundnut digger elevator integrated with a heap forming mechanism. The machine operated at an average cutting depth of 13 cm and covered a width of 60 cm under soil moisture conditions of 19.20% (dry basis). The

theoretical field capacity was estimated at 0.12 ha/h, while the effective field capacity was 0.0935 ha/h, resulting in a field efficiency of 80.47%. Digging efficiency improved with increasing forward speed, recording values of 84.18%, 85.23% and 86.36% at speeds of 1.5, 2.0 and 2.5 km/h, respectively. The corresponding pod quality values were 176.41 g, 180.21 g and 173.91 g, with pod damage percentages of 4.37%, 4.36% and 4.73%. The operational cost of the developed machine was calculated as ₹371.98 per hour.

Nikam *et al*. (2021) proposed a conceptual design for a groundnut harvester aimed at reducing labour dependency and ensuring timely harvesting. The proposed system integrates multiple operations including uprooting, conveying and pod stripping. The conveying unit lifts the plants and transfers them to a stripping mechanism, where pods are detached due to impact forces. The separated pods and plant residues are then directed into distinct collection units.

Shen *et al*. (2023) conducted an experimental investigation on a peanut digger-inverter for upright crops. An orthogonal experimental design was used to evaluate the effects of tractor travel speed, conveyor chain speed and inverting roller speed on performance indicators such as vine inversion rate, buried pod rate and pod loss. Under optimal conditions ($A_2C_2B_2$ combination), with tractor speed at 1.01 m/s, roller speed at 1.88 m/s and conveyor speed at 1.02 m/s, the vine inversion rate reached 74.29%, while buried pod and fallen pod rates were minimal at 0.14% and 0.33%, respectively.

12.5 Different digging blades

Tiwari and Jethva (2001) designed a two-row groundnut digging blade operated using a small tractor. The performance of the developed blade was evaluated and compared with conventional digging blades. The results indicated that the improved blade performed better in all major aspects. The observed effective field capacity, field efficiency, harvesting efficiency and fuel consumption were 0.126 ha/h, 77.8%, 94% and 2.4 L/h, respectively.

Suryawanshi *et al*. (2009) conducted a comparative study on different types of groundnut digging blades, including straight, inverted V-shaped and crescent-shaped designs. Their findings revealed that the straight blade required comparatively less draft force while achieving higher harvesting efficiency. Due to its simple design and better performance, the straight blade was considered most suitable for use in groundnut digging operations.

13. Materials and Methods

13.1 Location of experiment

The experiment will be conducted in the Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh.

13.2 Year of experiment: 2027-28.

13.3 Plan of work

The objectives shall be achieved through following plan of work:

1. Problem identification and project formulation.
2. Collection of review of literature and information regarding existing harvesting method and techniques.
3. Conceptual design of machine in CREO software.
4. Development of a peanut stack formation attachment to the existing groundnut digger shaker.
5. Design of experiment.
6. Layout of experimental plot.
7. Test procedure and field data sheet preparation.
8. Testing of the machine.
9. Thesis writing.

13.4 Existing Groundnut Digger Shaker

The groundnut digger shaker used in this study was a tractor-operated implement powered through the Power Take-Off (PTO) system. It comprised several essential components, including a main frame, digging blade, conveyor unit, depth control wheels, gearbox and windrowing rods. Each component played a significant role in the effective digging, separation and placement of groundnut plants.

The conveyor system facilitated the separation of soil from the uprooted crop, while the depth control wheels ensured proper operating depth during field operation. Power transmission from the tractor PTO was regulated through the gearbox to drive the conveyor mechanism efficiently. Additionally, the windrowing rods helped in arranging the uprooted plants into uniform rows for easy collection. The detailed specifications of the groundnut digger shaker are illustrated in Figure 1.

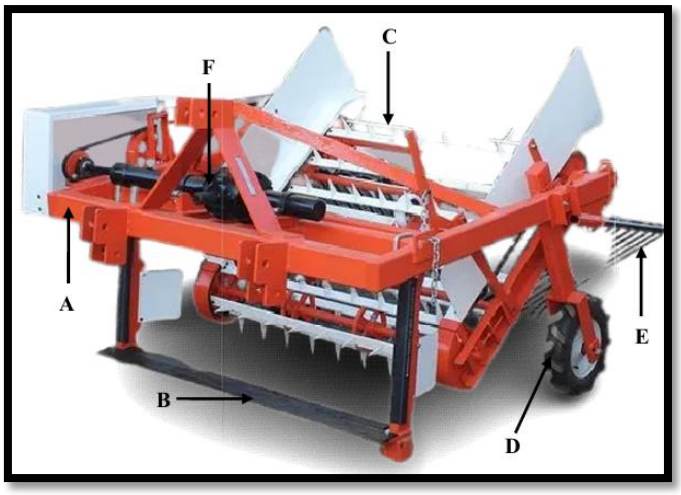

Figure 1. Schematic view of existing groundnut digger shaker

A. Main Frame B. Digging blade C. Conveyor
D. Depth control wheel E. Windrowing rods F. Gear box

The conventional groundnut digger-shaker machine lifts the crop, separates soil through a shaking mechanism and conveys the uprooted plants to windrowing rods for field drying (Figure 1). However, in the existing groundnut harvesting system, there is no provision for forming organized stacks of the harvested plants. As a result, manual labor is often required for collection and stacking operations. Considering this limitation, a peanut stack formation attachment was conceptualized and developed to be integrated with the existing groundnut digger-shaker, aiming to improve field efficiency and reduce post-harvest labor requirements.

13.4 Development of a peanut stack formation attachment to the existing groundnut digger shaker

The tractor operated groundnut digger cum shaker comprises of frame, gear box, conveyer (rice harvesting), bevel gears, digging blade, conveying rods, height adjustment pneumatic tires.

13.4.1 Power requirement

The power requirement of the developed machine will be determined by considering parameters associated with the implement as well as the prevailing soil conditions. For the analysis, the specific soil resistance of medium black soil in the study area is assumed to be 0.75 kg /cm^2 (Khurmi and Gupta, 2011).

$$P = \frac{S_R \times d \times W \times V}{75} \times \frac{1}{\eta_t} \quad \text{… Eq. 1}$$

Where,

P = Power requirement in HP

S_R = soil resistance in kgf/cm^2,

d = depth of cut in cm,

W = effective width of cut in cm,

V = speed of operation in m/s,

η_t = transmission efficiency

13.4.2 Power transmission system

The machine is designed to operate using power supplied through the tractor's Power Take-Off (PTO) system. This rotational power is transmitted from the PTO to the machine's gearbox, where it is appropriately regulated and distributed. Subsequently, the processed power from the gearbox is transferred to the drive shaft, which facilitates the motion of the belt mechanism.

13.4.3 Gear box

Power from the PTO will be transmitted to the gearbox, where it will be reduced to achieve the desired operating conditions. Various types of gearboxes with different reduction ratios are available in the market. The appropriate reduction ratio will be selected based on the calculated rotational speed (RPM) of the driven shaft and its diameter. For the present application, a gearbox with dual-side output will be selected to meet the operational requirements.

13.5 Performance evaluation of the machine

Table 5. Details of experimental field

Sr. No.	Variables	Parameters	Levels
1.	Independent Parameters	Forward speed (km/h)	S_1 = 2.0-2.5 S_2 = 2.5-3.0 S_3 = 3.0-3.5
		Speed of windrower (rpm)	N_1 = 10-20 N_2 = 20-30 N_3 = 30-40
2.	Dependent Parameters	Stack formation efficiency (%) Uncollected crop loss (%) Pod loss (%) Field capacity (ha/h) Field efficiency (%) Fuel consumption (L/h)	

***Above level will be subjected to change depending upon with preliminary trials of machine**

13.6 Experimental details

- ✓ Statistical design: large plot technique
- ✓ No. of treatment combination: 3 × 3 = 9
- ✓ No. of replications: 3

Table 6. Details of various treatment combinations

Sr. No.	Name of Treatment	Combination
1.	**Treatment 1** (T_1)	S_1N_1
2.	**Treatment 2** (T_2)	S_1N_2
3.	**Treatment 3** (T_3)	S_1N_3
4.	**Treatment 4** (T_4)	S_2N_1
5.	**Treatment 5** (T_5)	S_2N_2
6.	**Treatment 6** (T_6)	S_2N_3
7.	**Treatment 7** (T_7)	S_3N_1
8.	**Treatment 8** (T_8)	S_3N_2
9.	**Treatment 9** (T_9)	S_3N_3

13.7 Physical properties of groundnut plant

To develop a highly efficient and economically viable peanut stack formation attachment for integration with an existing groundnut digger-shaker, it is necessary to understand the relevant physical and mechanical characteristics of the groundnut crop. To achieve the goal, following parameters will be studied are:

Table 7. Details of experimental parameters

1.	Variety
2.	Maturity
3.	Plant height
4.	Plant canopy
5.	Plant population
6.	Row to row spacing
7.	Pod depth
8.	Root length
9.	Cropping pattern

13.7 Soil properties

13.7.1 Moister content of soil

Soil samples will be obtained from the experimental field and their moisture content will be determined using the standard oven-drying technique. In this method, the collected soil samples will first be weighed to record their initial (wet) mass.

Subsequently, the samples will be placed in a drying oven maintained at 105 °C for a duration of 24 hours. After drying, the samples will be reweighed to obtain their dry mass. The soil moisture content will then be calculated based on the difference between the initial and final weights, following the procedure outlined in (IS: 2720-2-1973).

$$\text{Moisture content} = \frac{\text{Initial weight of soil} - \text{Final weight of soil}}{\text{Initial weight of soil}} \times 100 \quad \ldots \text{Eq. 2}$$

13.7.2 Bulk density of soil

A metallic core cylinder will be employed for collecting undisturbed soil samples from the field. The samples will be obtained using a core sampler and their mass will be measured with a precision of 0.1 g. The oven-dry weight of each sample will be determined based on the measured moisture content on a wet basis. Bulk density will then be computed as the ratio of the dry mass of the soil to the corresponding core volume. (Punmia *et al*., 2009).

$$Bulk\ density = \frac{W - (W \times \frac{MC}{100})}{V} \times 100 \quad \ldots \text{Eq. 3}$$

Where,

W = Weight of moist soil collected (g)
V = Volume of metallic core (cm^3)
MC = Moisture content of the soil (%)

13.7.3 Cone index of soil

Soil strength is commonly expressed using the cone index, which serves as a key indicator of soil resistance to penetration by tillage or digging tools under field conditions. To characterize the soil condition, measurements will be taken within a depth range of 0 to 100 mm. A cone penetrometer will be gradually inserted into the soil up to the desired depth and the corresponding dial gauge readings will be recorded at specified intervals. The cone index values will then be determined using the standard equation (ASABE, 2013).

$$Cone\ index = \frac{F}{A} \quad \ldots \text{Eq. 4}$$

Where,

F = Soil penetration resistance (kg)
A = Cone base area (cm^2)

13.8 Machine Performance Parameters

The developed machine will be assessed under field conditions to determine its performance based on standard evaluation parameters. The study will focus on field

efficiency, overall pod loss, effective field capacity and fuel consumption (IS: 11235). The experiment will conduct to test and evaluate the performance of developed machine and considered parameters are:

13.8.1 Stack formation efficiency

$$Stack\ formation\ efficiency\ (\%) = \frac{No.of\ properly\ formed\ stacks}{Total\ No.of\ plants} \times 100 \quad \ldots \text{Eq. 5}$$

13.8.2 Pod loss

$$Pod\ loss\ (\%) = \frac{Weight\ of\ lost\ pods}{Total\ yield} \times 100 \quad \ldots \text{Eq. 6}$$

13.8.3 Theoretical field capacity

refers to the maximum possible rate at which it can cover a field under ideal operating conditions. It assumes that the machine operates continuously at its specified speed without any interruptions or losses and utilizes its full effective working width at all times. This represents a perfect scenario with 100% time efficiency and complete width coverage, without accounting for practical limitations such as turning, adjustments, or downtime (Mandal, 2016).

$$Theoritical\ field\ capacity\ \left(\frac{ha}{h}\right) = \frac{Effective\ working\ width\ (m) - forward\ speed\ (\frac{km}{h})}{10} \quad \ldots \text{Eq. 7}$$

13.8.4 Effective field capacity

The duration required to perform the effective field operation, along with the time expended on ancillary activities such as turning, cleaning and other interruptions, will be systematically evaluated and recorded (Mandal, 2016).

$$Effective\ field\ capacity\ \left(\frac{ha}{h}\right) = \frac{A}{T_p + T_{np}} \quad \ldots \text{Eq. 8}$$

Where,

A = Actual area covered, ha

T_p = Productive time, h (actual time required to cover area)

T_{np} = Non-productive time, h (Time lost for turning, making machine adjustments and other interpretations)

13.8.6 Field efficiency

Field efficiency is an important parameter used to evaluate the operational performance of agricultural machinery. It represents how effectively a machine

performs under actual field conditions. Field efficiency is calculated as the ratio of effective field capacity (the actual work accomplished) to theoretical field capacity (the maximum possible work under ideal conditions) and it is usually expressed as a percentage.

$$Field\ efficiency = \frac{\text{Effective field capacity}}{Theoretical\ field\ capacity} \times 100 \qquad \ldots \text{Eq. 9}$$

13.8.7 Wheel slip

Wheel slip of the tractor will be determined by placing visible coloured tape marks on the drive wheels. The tractor will be operated under identical field conditions and the distance travelled for ten wheel revolutions will be recorded in two cases: without load (D_1) and with load (D_2). Field markers such as pegs will be used to accurately note the start and end points of each run. The percentage of wheel slip will then be computed using the standard formula.

$$Wheel\ slip\ (\%) = \frac{(D_1 - D_2)}{D_1} \times 100 \qquad \ldots \text{Eq. 10}$$

13.8.8 Draft

The draft requirement will be determined using a dynamometer positioned between two tractors. One tractor will act as the pulling unit, while the second tractor, fitted with the digger, will be towed. The towed tractor will be maintained in a neutral gear condition and the digger will be operated under normal working conditions. During the operation, the force exerted will be measured and recorded through the dynamometer (Sharma and Mukesh, 2013).

13.8.9 Fuel consumption

The fuel consumption of the tractor during the digging operation will be determined by filling the fuel tank to its full capacity (up to the neck) before commencing the test. After completion of the operation, the tank will be refilled to the same level and the quantity of fuel added will be recorded. The fuel consumption will then be calculated and expressed in terms of litres per hour (L/h).

13.8.10 Cost analysis

The operational cost of the machine on an hourly basis will be estimated by accounting for both fixed and variable expenses. This calculation will follow the straight-line depreciation approach as outlined in IS: 9164-1979. Under this method, the value of the machine is assumed to decrease uniformly over its useful life, resulting in an equal annual depreciation charge.

14. Statistical Analysis

Statistical analysis of the experimental data will be carried out using a factorial completely randomized design (FCRD) under the large plot technique. This approach will enable the evaluation of the individual and interactive effects of different treatments on the observed parameters. The design ensures proper comparison among treatments and provides a reliable framework for assessing their influence on the measured variables (Panse and Sukhatme, 1957).

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